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Professionals' views of vernacular building materials and techniques for green building delivery in Ghana

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ABSTRACT

Vernacular architecture is associated with numerous advantages. However, its adoption in the development of sustainable buildings is not appreciated. This paper examines professionals' views of vernacular building materials and techniques for green building delivery in Ghana. A questionnaire survey was conducted among 54 built environment professionals. Data were analyzed using descriptive and inferential statistics. The findings suggest that the key vernacular materials for green building delivery are timber, bamboo, and laterite. It further suggests that the key vernacular techniques which are suitable for green building delivery are timber-framed construction, sun-dried brick walling/Adobe, and rammed earth or Atakpame walling. This study is useful for built environment professionals who are active in the construction industry and who are responsible for green building delivery decision making during the design and construction stages of buildings.

Introduction

The increased concern of the negative impacts associated with construction activities in recent years has called for green or sustainable building developments from both the public and private sectors. Green building construction is not entirely new because it has its trace from vernacular buildings where some materials, strategies, and techniques from vernacular architecture are incorporated [42]. The use of locally available construction materials was widespread until the industrialized revolution which saw the increased use of new industrially produced and standardized building materials, and which led to the homogenization of the use of different construction approaches [16]. Modern architecture which makes use of industrially produced materials has given rise to a universal architecture that is highly dependent on energy consumption [16]. The world is now facing a string of serious energy and environmental challenges [4]. In a report by the International Energy Agency, IEA, (2013), fossil fuel reserves which contribute to over 80% of the world's total primary energy consumption has declined. The demand for energy is on a steep rise, and energy prices keep fluctuating [4].

The construction industry has a strong interaction with global energy and environmental problems [4]. Buildings are responsible for more than 40% of global energy consumption and over a third of the total greenhouse gas emissions [4]. Since a building uses energy throughout its life, the demand for energy in buildings in their lifecycle is both direct and indirect

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[4]. Due to this problem, energy efficiency and comfort conditions have become one of the crucial concerns in the design and decision-making phase for sustainable or green buildings. According to Mumovic and Santamouris [31], because buildings play crucial roles in mitigating energy and environmental issues, applying energy-efficient and sustainable buildings has received serious attention worldwide, especially, in the residential sector. The IEA (2014) indicated that the residential sector represents 26% and 17% of world energy consumption and carbon dioxide production respectively. The second half of the 20th century saw resources that once provided bounties for mankind and which were assumed to be inexhaustible facing exhaustion [49]. Following the wasteful resource consumption, population increase and fossil fuel usage, mankind is now faced with several disasters like environmental pollution, ozone layer depletion, global warming, deforestation, among other things [49].

Since the root of most of these problems has been linked to the construction industry, Alrashed et al. [4] indicated that many forms of sustainable residential buildings (e.g. low-energy homes, zero-energy homes, passive houses, etc.) have been developed across the world to address some of these concerns. This assertion is reflected through the numerous buildings which are being certified sustainably [4]. The Leadership in Energy and Environmental Design (LEED) Directory (2015) indicated that over 70, 000 buildings have been certified worldwide with LEED. There have been similar reports in Europe where over 8,500 projects are reported to have been certified with the Building Research Establishment Environmental Assessment Methodology (BREEAM) [4]. Similar scenarios are further reported in Australia with the Green Star Certification as well as Japan with the Comprehensive Assessment System for Built Environment Efficiency [4]. In Africa, the green movement is on the rise, and Ghana can now boast of some buildings which have been certified with LEED, EDGE and Green Star [3,5]. These developments are very important.

Literature reports that since traditional buildings are true reflections of sustainable construction, there is the urgency to revisit past experiences, especially, with regards to these traditional constructions. Such construction methods have significant roles to play in the future of construction [16]. These traditional constructions also referred to as vernacular architecture involved the use of vernacular materials, techniques and strategies, hence, without the use of such vernacular or local materials and techniques in the construction of new buildings, the sustainability aspect of it becomes a problem. Fernandes et al. [16] indicated that using alternative materials and techniques like the vernacular ones can reduce the total embodied energy of a building.

Studies have postulated that vernacular architecture consumes fewer energy whiles leaving little environmental impact to achieve good indoor thermal comfort [12]. This type of architecture is considered to be very advantageous to modern sustainable architectural design [12]. Several sustainable building projects worldwide have experienced the introduction of vernacular building materials and techniques [4,22,23,46]. Considering the majority of studies conducted on the use of local materials and techniques in sustainable building construction, it could have been easier to settle on any of the proposals made from such studies. However, contextually, that would not be right because being able to identify vernacular materials and techniques peculiar to a particular location comes with several advantages. This, therefore, makes it important for this study to be conducted to identify those vernacular materials and techniques which are peculiar to the Ghanaian setting. Literature has greatly reported on this issue. For instance, Tawahya et al. [46] examined the significance of local architecture regarding the creation of sustainable buildings in a Mediterranean city in Palestine. Hamard [22] rediscovered the vernacular adaptive construction strategies used for sustainable modern buildings. Hashemi [23] also examined the role of vernacular strategies in the design of energy-efficient residential buildings in Iran. In Turkey, the prospects of vernacular or local materials for sustainable housing design was explored by Kuyrukçu and Kuyrukçu [28].

These lists go on further as reported in the literature. Despite the numerous studies conducted on vernacular materials in other countries, empirical studies identifying the vernacular building materials and techniques important for green building development in Ghana is lacking. This study therefore aimed at examining professionals' views of vernacular building materials and techniques for green building delivery in Ghana.

Literature review

Vernacular architecture: Definition, materials, and techniques

Glassie [20] defined vernacular architecture to mean the unconscious realization and embodiment of the culture of the society with the necessities of the people in nature. According to Fernandes et al. [16], this type of architecture expresses the culture of a group of people and relates it to their territories so that the necessary changes and adjustments can be made in response to the continuous social and environmental constraints. The term vernacular stems from the Latin word 'vernaculus' and it is normally translated to mean domestic, native or indigenous [42]. This type of architecture came into being when humans felt the need to use the natural resources around them to create the needed shelter for themselves [25]. It is also seen as the direct responses to context and resources including materials and techniques using available potentials such as indigenous skills of the local passed on from generation to generation [25].

Alrashed et al. [4] indicated that history has extensively reported on how factors such as culture, weather, and geographical locations shaped the use of vernacular materials and technologies by indigenes of localities worldwide. For instance, vernacular materials like clay and mud (Adobe) have received widespread usage within the construction industry worldwide for thousands of years [9]. Several modern buildings have been constructed from adobe and such buildings are scat-

tered in many countries with different climatic conditions [21]. Quite recently, Costa et al. [11] also reported on the use of earth/laterite as a vernacular material that is significant for modern types of construction.

There are reports on several vernacular building techniques that have equally been applied to modern sustainable buildings for passive designs. In hot desert climates where cooling and daylighting are sought after, several vernacular techniques have been used in the construction of buildings [4]. Such techniques are identified to include roof ponds, domes, air vents, cooling towers among others [4]. The selection of the techniques and materials for such buildings is usually dependent on the desired benefits, as well as the local availability of construction materials and skilled labor [4]. Also, vernacular techniques such as adobe and rammed earth construction, and wattle and Daub are well reported in the literature [33].

Vernacular architecture in Ghana

Architecture in Ghana can be grouped into the northern, the middle, and the southern zones respectively. Schreckenback [44] indicated that the buildings located within these zones are unique because of the materials and techniques which are used in their construction. Discussed below are some of the vernacular building materials and techniques used for the construction of buildings within the three zones

Vernacular building materials in Ghana

Some of the vernacular building materials which have been in use in Ghana and other parts of the world are bamboo, timber, laterite, grass/thatch, clay, etc. This section reviews the literature on those vernacular materials which are used for construction in Ghana.

Bamboo: Bamboo is a renewable building material, environmentally friendly and widely available in most countries [48]. As a vernacular building material, it is very much in abundance within the tropical and sub-tropical regions of the world. van der Lugt et al. [48] further reported that it is very versatile and has high strength and low weight. In the northern belt of Ghana, for instance, it is a common material used for wall structures. In Asia, it is a very common building material in the south-eastern part. Trials conducted for tensile strength reveal that bamboo incredibly outperforms most of the other building materials, including steel reinforcement [48]. It gains its strength through its hollow tubular structure. It has been classified as a very economic construction material because of its growth, harvest and transport rates [48]. Despite its numerous advantages concerning its properties, it is known to be prone to buckling. However, studies show that this weakness can easily be corrected. This has therefore made bamboo the fastest growing renewable natural building material in the world [48].

Timber: Until recently, timber used to be part of the natural resources which are readily available in Ghana. Timber products used for construction in Ghana are classified either as structural or non-structural [43]. In Ghana, structural timbers are used in the construction of load-bearing walls, frames, etc. The non-structural timbers, on the other hand, are normally used for non-structural works like wall sidings, ceilings, and floors. As a versatile material with desirable properties, studies have shown that existing timber houses in Ghana have stood the test of time as compared to those constructed with some conventional materials [7]. Among its desirable properties, timber is durable, can withstand fire attacks for a good time, has good thermal conductivity and expansion, and is attractive [7].

Earth: Another important vernacular material is earth. It has been defined to include soils that are uncemented mineral grains and which are usually formed by the weathering of rocks including organic matter and water [37]. Earthen materials if used and managed correctly does not lead to the depletion of resources, increase in pollution or biological changes when compared to the conventional building materials [37]. Earthen construction materials are one of the most experimented technologies in the current search for economically and environmentally sustainable housing [1]. Earthen construction materials include laterite, clay blocks (adobe), clay soil, rammed earth among others [1,37]. Discussed below are two common examples of earthen materials, i.e. laterite and clay.

Laterite: Laterites are defined to include “all the reddish, tropically weathered residual and non-residual soils that include laterite rocks” [50]. It is a vernacular material that can be found all over the world. It is especially common in countries where there are higher levels of rainfall [27]. Laterite is one vernacular material that has been in use for ages past. In Africa, it is a material that is widely used by the indigenes of various countries [2]. Among the reported characteristics of laterite is that it is cheap, socially acceptable and it is environmentally friendly. The geotechnical behavior of laterite is controlled by the mineralogical composition, micro-fabric and geochemical environmental conditions [37]. Laterites are composed of both cohesive and cohesionless soils and are in the form of gravels (sizes range between 2 and 20 mm), sands (sizes range between 0.06 and 2 mm), silts (sizes range between 0.002 and 0.06 mm), and clays (sizes smaller than 0.002 mm) [37]. It is classified as an excellent engineering material with a general compressive strength in the range of 0.5-1.5 MPa [37].

Clay: It is a material used for sustainable traditional building [43]. Clay normally has particle sizes of less than 0.002 mm [37]. Clay has its particles coated in a thin film of absorbed water molecules [30]. Unlike sand and gravels clays are not stable but are quite sensitive to variation in humidity levels [30]. A typical product of clay is the clay bricks. Clay bricks are old traditional building materials used worldwide. They are bricks that are environmentally friendly, energy-efficient and locally manufactured. According to Sharma [45], clay has become an important indigenous material preferred and recommended by professionals for various kinds of green buildings. Following the identification of some key features (energy efficiency, thermal superiority, durability, better indoor environment quality, etc.) associated with clay, it has become the choice of architects worldwide in providing more sustainable buildings.

Fig. 1. Typical Adobe buildings in Ghana (source: hiveminer.com).

Fig. 2. Typical Wattle and Daub buildings (Source: [8]).

***Grass*:** It is a very common vernacular material that is used for roof construction, especially, in the northern regions of Ghana. Rashida and Dilshad [40] indicated that the various types of roofing that can be constructed by thatch include but not limited to double-pitched, gable-ended or hipped and conical or hemispherical. In the construction of any of such roofing types, smaller members of sticks or bamboo are tied to the rafters, mainly timer, using either raffia or twine. Rashida and Dilshad [40] further indicated that once the structure is completed, various packs of fresh grass, normally, in several layers of three to four are fastened to it and this serves as the roof covering. A typical example of material modification of grass is the thatch. Thatch is a locally available natural material made from grass which has a high insulation value. It is made from grasses that are cut from the stalk of the thatching grass and loosely bundled with a thong of twisted twine. It can withstand strong winds and scour from wind-blown sand. In Northern Portugal, thatch is used to respond to cold winters, reduce heat losses and take advantage of solar radiation [16].

Vernacular building techniques in Ghana

Various vernacular building techniques that have been in use in Ghana and other parts of the world are described to include the following: sun-dried brick walling/Adobe construction; Wattle and Daub; Timber Framed Construction; Pile Dwellings; and Rammed Earth Construction.

Adobe construction: Adobe construction has been in existence for a good number of years [11]. Following the series of studies undertaken on this kind of construction, it has been concluded that there is currently about 30% of the world's population that live in buildings constructed with adobe or earth [11]. Also referred to as earth construction, Adobe construction comes with several economic and environmental benefits [11]. Fratini et al. [18] posited that these benefits manifest themselves especially in developing countries where there are serious problems with the cost of materials, labor, construction methods, and the likes. In the view of Bui et al. [10], the cost associated with this method of construction is cut short because of the use of materials available within the specific community. Costa et al. [11] iterated that the material used makes this kind of construction very beneficial to the environment because there are no sophisticated processes involved. Fig. 1 depicts the typical adobe buildings in Ghana.

Wattle and Daub: The Wattle and Daub is a method of constructing walls highly associated with indigenes living in buildings in the southern part of Ghana [15]. With this method of construction, fresh earth is placed on a support [11]. There are two parts involved in this construction technique [33]. In Ghana, this method of construction takes quite a different kind of approach. According to Essienyi [15], the anticipated outline of the building is usually marked out by setting out. At regular intervals, the required trenches or pits are then excavated following the outline of the building. When all the pits are completely excavated, vertical props are inserted into them and firmly held in position with stones rammed around the base. The other framing systems are then carried out until the structure is complete and ready to be occupied [15]. Fig. 2 shows typical Wattle and Daub structures for indigenes in Ghana.

Fig. 3. A typical pile dwelling in Ghana (source: amedzofevillage.com).

Fig. 4. A typical rammed earth building in Ghana (Source: https://www.dw.com/en/in-ghana).

Timber framed: Timber framed construction technique is mostly used in the coastal and forest belts of Ghana. This type of construction requires the precision cutting of materials to create timber members of the required sizes to be used in the construction. The absence of mechanical fasteners during the primeval times in Ghana made this kind of construction quite difficult. However, local indigenes could confidently erect timber structures by hand [24]. The timber-framed construction technique is reported to be important because of the use of wood which is a high-performance building material highly beneficial to the environment.

Pile dwellings: Pile dwellings also referred to as floating buildings are usually required in wetlands or communities located within swampy areas. Puspitasari et al. [39] indicated that these kinds of construction techniques are usually initiated by the climatic condition within the specified location or region. Structures within such vicinities require a floating structural system that can enhance free vertical movement to follow the changing water levels and its movement in all directions [39]. In Ghana, a typical example of this kind of architecture is located at Nzulezu, located on Lake Tandane in Ghana's western region. The method of construction used for such dwellings is fully described by Essienyi [15]. Fig. 3 shows a typical pile dwelling for indigenes at Nzulezu in Ghana.

Rammed earth: Rammed earth construction involves a mixture of raw materials like soil, gravel, and sand [11]. Materials of this nature are highly non-combustible, thermally massive, very durable and very strong as well [43]. During this kind of construction, the rammed materials are usually compacted in several layers between formworks [11]. It is a unique method of construction which can only be carried out by local practitioners highly experienced in its application. In Ghana, this technique is usually referred to as 'Atakpame'; a name which was coined because of its linkage to the Ewe ethnic group in Ghana, Togo, and Benin [15]. The detailed description of this construction is vastly reported by Essienyi [15]. Fig. 4 shows a typical eco-friendly rammed earth building in Ghana.

Vernacular Architecture and Green Building

Sustainable design and architecture both have a common aim, thus, producing environmentally friendly constructions that are compatible with the surrounding conditions of a particular region and that can last for a long period [42]. Applying vernacular techniques and materials to buildings are seen to be sustainable options for the buildings' improved energy, environment, and thermal performances. Vernacular architecture has important features like durability and versatility, hence, the necessity of selecting building materials in the nearest environment which are the vernacular building materials and adopt their corresponding strategies and techniques into green buildings. Vernacular architecture principles respect nature and are climate-conscious, user friendly and respect the culture and tradition of the community at large and most importantly contextual [25].

Green building is an approach that emphasizes the place of buildings within both local ecosystems and in the global environment. The scope covered by green buildings includes the building's size and shape, its usefulness, the stability of the material used in the construction of the building, its embodied and recurring energy loads and outputs of pollution, its

ability to last longer and survival of disrepair, among other things. The ecological aspect of green is aboriginal to vernacular architecture (Jain n.d.). Those who have lived with and encountered nature have been in the best position to explore and have created the greenest and the most sustainable elements which are employed today in producing green or sustainable buildings [42]. The buildings, huts, habitats, and structures of such people are made from the material which their sites offered them. In the olden days, some habits exhibited by indigenes such as the harvesting and conservation of rainwater in the desert areas, and the use of impermeable stone slabs, among other things are what is exhibited in the most energy-efficient buildings currently (Jain, n.d.). Other practices such as sprinkling water on porous mud floors to provide a satisfactory indoor environment both in the day and night times have been transformed into the wind towers currently used in green buildings (Jain, n.d.). These instances indicate that local architecture provided a more friendly environment for indigenes to operate in and out of their buildings [19].

Currently, most green buildings worldwide have been developed to make use of most of these vernacular materials and techniques. In Africa, the green movement is on the rise, and Ghana is gradually buying into the idea of moving green. A typical example of a green building constructed with a vernacular material, strategy and technique is the One Airport Square building. This building was certified under the Green Star SA-Ghana certification tool [5]. In rating the building, it achieved a certification level of four stars, and unique among its features is the incorporation of vernacular building strategies. Agyekum et al. [3] indicated that the aesthetic elements and architectural design of the building were based on traditional local art. This is a clear indication of the embodiment of the Ghanaian culture by incorporating the look of a palm tree, which is predominant in Ghana, in the design of the edifice.

Research methodology

The purpose of this research was to examine professionals' views of the vernacular building materials and techniques which are important for green building delivery in Ghana. A quantitative research approach was used. This approach allows for the use of structured questionnaire surveys, enabling researchers to generalize their findings from a sample of the population.

Population and sample size

The unit of analysis from which the primary data was collected was the Built Environment Professionals located in Accra and Kumasi. Emphasis was however laid on the fact that such professionals had adequate knowledge and experience of the green building concept as well as vernacular building materials. These locations (Accra and Kumasi) were chosen among the lot in the country because they are highly industrial areas and most built environment professionals are based there. Though there exist quite a good number of built environment professionals within the study locations, getting those professionals who had in-depth knowledge concerning the issue under investigation was difficult. Rowley [41] indicated that when faced with such a problem it is good to use a non-probability sampling approach to obtain the required samples. Since the green building is somewhat new in the Ghanaian system, most professionals tend to shy away when approached for their inputs concerning the concept.

This problem greatly influenced the responses of the study. Readily available participants were located using purposive sampling and by referrals using the snowball method, other professionals were contacted for the study. In all, a total of 54 professionals were interviewed. The purposive and snowball sampling approaches (non-probability sampling approaches) became relevant because the researchers did not have a clear view of the population (i.e. those with knowledge and experience in the green concept) to which they were seeking to generalize, hence, making it difficult to compile a complete sampling frame for the study. This problem of not having the adequate idea of such respondents have resorted in other green building-related studies in Ghana adopting a more qualitative approach to reach respondents who are hard to reach [3,5,35,36].

Data Collection

Data gathering is crucial in research, as the data contribute to a better understanding of the theoretical background. The most suitable instrument or tool that can be used to collect quantitative data is a questionnaire. The data collection technique adopted for the study was the questionnaire survey. The formats adopted for the questions in the questionnaire are the closed-ended, where respondents were limited to choosing between several given options from the Likert response scale of 1 to 5 that was provided. The questions were designed to be as simple and unambiguous as possible. Confidentiality of responses by participants was taken into consideration to enable them to answer the questions sincerely and confidently as much as possible.

The survey questionnaire was developed following an extensive review of the literature. The questionnaire developed was grouped into two major sections (Sections 1 and 2). Section 1 sought to find out the background information of respondents. This included the name of their professional body, their profession, their levels of experience in green construction and the construction industry as a whole. Section 2 was further divided into two sub-sections. The first subsection required the respondents to score the selected vernacular building materials on a Likert scale of 1 to 5 (where 1 = not important, 2 = less

Table 1
Demographic characteristics of respondents.

The current profession of Professional	Frequency	Percentage
Quantity Surveyor	28	52%
Planner	1	2%
Architect	9	17%
Land Surveyor	1	2%
Engineer	10	18%
Others	5	9%
Experience of professional in Ghanaian Construction Industry		
<5 years	19	35%
5-10 years	15	28%
>10 years	20	37%
Experience of professional in Green Building Construction		
<5years	32	59%
5-10 years	15	28%
>10 years	7	13%

important, 3 = moderate, 4 = important, 5 = very important) based on their importance for green building delivery. The second subsection further required the respondents to score on a Likert scale of 1 to 5 the importance of the selected vernacular building techniques for green building delivery (where 1 = not important, 2 = less important, 3 = moderate, 4 = important, 5 = very important). The questionnaires were distributed and retrieved in-person to improve the response rate.

Analysis and interpretation of the data

The data obtained was analyzed using SPSS Version 22. The tools selected for the analysis were the mean score ranking, one-sample t-test and the Analysis of Variance (ANOVA). In this study, the higher the mean value (greater than or equal to 3.0), the more important the vernacular building material or technique is seen as important to green building delivery.

In ranking of the materials and techniques, at the instance where two or more factors had equal mean values, the factor with the smallest standard deviation was assigned the highest rank. Following this, against a mean value of 3.0, the one-sample t-test was conducted to determine the significance of the mean values of the important vernacular building material and technique. The one-sample t-test was conducted at a 95% confidence level. The one-way ANOVA was also employed in this study. One-way ANOVA is a suitable statistical method that examines the differences between mean values from different groups of people [38]. In this study, because the respondents were from different Professional backgrounds (i.e. Ghana Institution of Surveyors, Ghana Institution of Engineers, Ghana Institution of Planners, Ghana Institution of Architects, Chartered Institute of Buildings, and others), the ANOVA was used to examine the statistically significant differences in mean values from the respondent groups.

Results

Demography of Respondents and firms

Table 1 summarizes the demographic characteristics of the respondents and their professional bodies. Almost all the respondents were actively involved in the practice of their professions. From the respondents' practical experiences in their various industries, the majority (35, 65%) had more than 5 years of experience. The remaining 19 (35%) had less than 5 years of working experience. With the experience in green building delivery, 32 (59%) of the respondents had less than 5 years of working experience with 22 (41%) of them having more than 5 years of experience. This observation is not so disturbing because green building development in Ghana is still at its infancy [3,5].

Vernacular building materials important for green building delivery

Vernacular building materials are known to have certain features and characteristics that make them potential contributors to sustainable housing delivery. Based on this, respondents were required to score the identified vernacular materials according to their level of importance. Table 2 shows the mean scores (MS), standard deviations (SD), standard errors (SE) and the *p*-values of the eight vernacular building materials that were assessed. Table 2 further revealed that the mean values of the importance of the vernacular building materials range from 2.576 to 4.537. From the one-sample t-test, it was shown that the mean scores of six out of the eight vernacular building materials were statistically greater than the mean value of 3.0. This finding indicates that these vernacular building materials are important for the delivery of green building in Ghana. For the vernacular building materials "Sandcrete blocks" and "Grass", in addition to the mean values, 2.625 and 2.576 respectively which were less than 3, their p-values (0.181 and 0.907 respectively) were also greater than 0.05. This implies that the importance of these vernacular building materials to green building delivery was not perceived as statistically significant.

Table 2
Mean values for vernacular building materials.

Materials	Mean	Std. Deviation	Std. Error	P-value	Rank
Timber	4.537	0.66	0.090	0.000	1st
Bamboo	4.204	0.88	0.119	0.000	2nd
Laterite	4.074	0.97	0.132	0.000	3rd
Sand	3.926	0.93	0.126	0.001	4th
Clay/Clay bricks	3.926	1.15	0.156	0.009	5th
Stone	3.815	1.07	0.145	0.034	6th
Sandcrete block	2.625	1.20	0.164	0.181	7th
Grass	2.576	1.16	0.158	0.907	8th

Table 3
ANOVA test results for vernacular building materials.

Materials	df	F cal.	F tab.	S/NS	Sig.
Timber	53	2.408	2.40	S	0.05
Bamboo	53	0.736	2.40	NS	0.6
Laterite	53	2.289	2.40	NS	0.06
Sand	53	1.547	2.40	NS	0.193
Clay/Clay bricks	53	1.83	2.40	NS	0.125
Stone	53	1.707	2.40	NS	0.151
Sandcrete block	53	1.479	2.40	NS	0.214
Grass	53	1.992	2.40	NS	0.097

***Key**: **S:** significant difference in mean values. **NS**: No significant difference in mean values.*

Table 4
Mean values for vernacular building techniques.

Techniques	Mean	Std. Deviation	Std. Error	p-value	Rank
Timber Framed Construction	4.093	0.900	0.122	*0.000*	1st
Sun - dried brick walling (Adobe)	3.852	*1.120*	0.153	*0.025*	2nd
Rammed Earth or Atakpame walling (from laterite)	3.593	*1.170*	0.160	0.000	3rd
Straw bale method	3.407	*1.140*	0.155	0.014	4th
Wattle and Daub	3.333	*1.010*	0.137	0.026	5th
Pile Dwellings	1.864	*1.080*	0.146	0.107	6th
Mashrabiya	1.534	0.960	0.131	*0.231*	7th

From Table 2, The top three vernacular building material that are of high importance to green building delivery are Timber (MS = 4.537, SD = 0.66), Bamboo (MS = 4.204, SD = 0.88) and Laterite (MS = 4.074, SD = 0.97).

While the ranking indicates the respondents' views of the importance of the vernacular building materials for green building delivery, inferential statistical analysis is required to establish whether the differences in the views of the respondents are significant. Table 3 shows the results from the ANOVA.

From Table 3 it can be observed that only one material, *Timber*, gained a different perception among the category of respondents, hence, the null hypothesis for that material was rejected. The F_{cal} value (2.408) was greater than the test statistic, F_{tab}, value (2.40). This implies that the categories had statistically different means for the material *Timber.* However, there was no difference in the perception of respondent categories concerning the remaining materials. They all had their 'F calculated' (Fcal) values lesser than the test statistic value (2.40). This implies that the respondent categories had no statistically different means for these materials.

Vernacular Building Techniques important for Green Building Delivery

Vernacular building techniques have generally been identified to be very useful in green housing for comfortable living. Based on this, respondents were required to score the identified vernacular building techniques according to their level of importance. Table 4 shows the mean scores, standard deviations, standard errors and the *p*-values of the seven vernacular building techniques that were assessed. From Table 4, the mean scores of the importance of the vernacular building techniques range from 1.534 to 4.093. The one-sample t-test further indicated that the mean values of five out of the seven vernacular building techniques were statistically greater than the mean value of 3.0, an indication that these vernacular building techniques are significantly important for the delivery of green building in Ghana.

For the vernacular building techniques "Pile dwellings" and "Mashabiya", in addition to the mean values, 1.864 and 1.534 respectively which were less than 3.0, their p-values (0.107 and 0.231 respectively) were also greater than 0.05. This implies that the importance of these vernacular building techniques to green building delivery was not perceived as statistically significant.

Table 5
ANOVA test results for the vernacular building techniques.

Techniques	df	F cal.	F tab.	S/NS	Sig.
Timber Framed Construction	53	1.176	2.40	**NS**	0.335
Sun - dried brick walls (Adobe)	53	0.898	2.40	NS	0.49
Rammed Earth or Atakpame walls	53	1.448	2.40	NS	0.224
Straw bale method	53	0.679	2.40	NS	0.642
Wattle and Daub	53	1.687	2.40	NS	0.156
Pile Dwellings	53	1.6	2.40	NS	0.178
Mashrabiya	53	0.636	2.40	NS	0.674

***Key**: **S:** significant difference in mean values. **NS**: No significant difference in mean values.*

From Table 4, the top three vernacular techniques that are of high importance to green building delivery are "timber-framed construction (MS = 4.093, SD = 0.900)", "Sun-dried brick walling (MS = 3.853, SD = 1.120)", and "Rammed earth or Atakpame walling (MS = 3.593, SD = 1.170).

To establish whether the differences in the views of the respondents are significant the ANOVA was further conducted, and the results are shown in Table 5. Inferring from Table 5, there were no significant differences in the views of the respondent categories concerning the techniques. This is because all the variables had their F_{cal} values lesser than the ANOVA test statistic value, F_{tab}, of 2.40.

Discussion

Key vernacular building materials important for green building delivery in Ghana

The construction industry is well known for its energy-intensive practices highly responsible for extensive carbon emissions, large consumption of non-renewable materials, and environmental degradations, hence, governments in various countries worldwide have enacted laws for the construction industries to shift towards using more greener materials for their construction [17]. This involves the use of vernacular building materials which are seen to positively impact green building delivery. From the results, the top three vernacular building materials that are of high importance for green building delivery are "Timber", "Bamboo" and "Laterite". The vernacular building material "Timber (MS = 4.537)" was ranked first, a reflection of the fact that the professionals attach great importance to timber as a vernacular material that could be used in green building delivery in Ghana. Sustainable timber as a vernacular building material worldwide is seen to have a very low negative impact on the environment, hence, when used in green buildings has the potential to minimize the adverse environmental impacts. As a result of this, timber-based construction systems have gained ground in the delivery of green buildings. Studies have shown that whereas manufactured building materials emit carbon in production, timber has the potential to consume the carbon generated at $1t/m^3$.

According to UN-Habitat [47], sustainably harvested timber is the most environmentally friendly of all the conventional building materials. This assertion is justified by the fact that timber has the lowest emissions of greenhouse gases than any conventional building material. Despite the numerous advantages associated with timber as a vernacular material for green building delivery in Ghana, the ANOVA results showed that the respondents had different views concerning the use of timber in construction. The differing views could be attributed to the current condition of the rain forest and its rate of depletion which has not only sparked serious debates in Ghana but the entire world [14]. This notwithstanding, Eshun et al. [14] further indicated that the creation of a more sustainable industrial development of wood extraction and procession in Ghana could protect and improve the natural environments of local communities and help achieve sustainability in the use of timber for green building delivery.

In addition to timber, the respondents ranked "Bamboo (MS= 4.204)" as the second vernacular building material important for green building delivery in Ghana. The UN-Habitat [47] indicated that over the years, bamboo has been accepted and used as a vernacular building material in the construction industry. This increased popularity is as a result of environmental sustainability [47]. This material has similar properties as timber, and it often uses analogous techniques of construction framing [47]. The importance of bamboo as a vernacular building material can be seen in all the different aspects of sustainability, i.e., environmentally, economically and socially. It's potential for environmental sustainability is apparent across many disciplines [47]. Nguyen [32] indicated that because of its aesthetic features, it is used as sustainable interior design for most green buildings in Vietnam. Bamboo is present in many countries worldwide and in the cultural sense when promoted, can mean promoting local methods of construction, a means of reinforcing local culture and history.

In Ghana, for instance, Opoku et al. [34] indicated that several bamboo species can be used to replace the dwindling timber species. Economically the value of bamboo and rattan is rated at 2-3 billion US Dollars worldwide [47]. Studies have shown that the bamboo industry in China employs 5 million people, an implication that bamboo products can stimulate local economic development and create employment opportunities [47]. Socially, this material can assist its producers to develop sustainable livelihoods. These benefits associated with bamboo indicates that the respondents believe there is much more to it than just using it as a vernacular material in the delivery of the green building.

The third key vernacular material which the respondents indicated as important in the delivery of green building in Ghana is laterite (MS = 4.074). Laterite, an earthen material is the most locally available, abundant and cheap material since the dawn of humanity [29]. It is an environmentally friendly material to build with [29]. Its significance as a vernacular building material is extensively reported [6,13,29]. Earth buildings are climatically adaptable and possess energy-saving qualities [29]. The importance of laterite as a vernacular building material can also be seen in all the different aspects of sustainability, i.e., environmentally, economically and socially.

According to UN-Habitat [47], lateritic materials have a relatively low environmental impact because of its local availability, abundance, and ease of extraction. Construction with laterite will mean the addition of a few natural and sustainable materials which means a great advantage to the environment. In the social aspect, the advantages associated with the use of laterite for green building delivery can be made known to the public. This can help deal with the stigma associated with living in buildings constructed with laterite. In the economic sense, promoting lateritic materials for green building delivery where there is a tradition of earth construction, especially in Ghana, can help develop skills and expertise that may be advantageous for securing work in the future [47]. The perception of the respondents on laterite as a vernacular material suitable for green building is therefore in line with all the three areas of sustainable development.

Key vernacular building techniques important for green building delivery in Ghana

The results again indicated that the top three vernacular building techniques that are of high importance for green building delivery are "timber-framed construction", "Sun-dried brick walling/Adobe (from clay)", "Rammed earth or Atakpame walling (from laterite)".

The vernacular building technique "timber-framed construction (MS = 4.093)" was ranked first, a reflection of the fact that the professionals attach great importance to timber-framed construction as a vernacular technique that could be used in green building delivery in Ghana. In Ghana, timber-framed construction has been a technique used by most of the locals in constructing buildings. Traditional timber-framed construction involves the creation of framed structures of wood to build residential and other structures. Timber-framed construction is one of the oldest known building techniques worldwide [26]. Due to the sturdy and resilient qualities of timber as a vernacular material, and the ease of construction of buildings with timber, this construction technique has gained popularity in more recent construction techniques. The respondents ranked this technique as important in the delivery of green buildings because of the numerous advantages associated with it. In terms of construction, it is faster to erect, easy and cost-effective, especially, when working on difficult terrains and slopes [26]. It is also eco-friendly, with a low embodied energy characteristic, especially, if the structure is built from sustainable vernacular materials. Some of these qualities make it highly suitable as a vernacular material important for green building delivery [26].

The sun-dried brick/block walling/Adobe and the rammed earth or 'Atakpame' techniques were also ranked by the respondents as the second (MS = 3.852) and third (MS = 3.593) key vernacular building techniques which are important for green building delivery in Ghana respectively. The rammed earth walling technique (mainly from laterite) is a vernacular building technique that has been in existence for years, tracing its use back to Mesopotamia around 10,000 BC [11]. Studies have shown that there is currently about 30% of the world's population that live in buildings constructed with either adobe (clay brick) or earth (laterite) [11]. This construction technique can be found among different ethnicities found throughout the world. Currently, in most countries, it is still the major construction technique [11]. The respondents consider these construction techniques to be important for green building delivery in Ghana because of the reported economic and environmental benefits associated with it. Fratini et al. [18] indicated that in developing countries where the cost of materials and construction techniques far outweighs that of labor, this technique could be encouraged. Costa et al. [11] iterated that in addition to its environmental and economic benefits, it also possesses social and cultural benefits, hence, the need to encourage it in the delivery of the green building.

Conclusion

Issues concerning energy consumption in buildings, carbon emissions resulting from the use of some materials and issues of sustainability are vastly reported in the literature. However, there is little attention to the importance of vernacular materials and techniques in the delivery of green buildings. Vernacular building techniques enhance and promote the use of local materials within the vicinity or environs of the proposed project. This study was undertaken to examine the views of professionals on vernacular building materials and techniques important for green building delivery in Ghana. The findings suggest that the key vernacular materials important for green building delivery are timber, bamboo, and laterite. The findings further suggest that the key vernacular techniques which are suitable for green building delivery are timber-framed construction, sun-dried brick walling/Adobe (mainly from clay), and rammed earth or Atakpame walling (mainly from red laterite).

This study was conducted to fill a necessary gap that tries to draw the attention of built environment professionals to the possibility of incorporating vernacular materials and techniques in green building delivery. In addition to filling this gap, the findings should help built environment professionals responsible for decision making during the design and construction stages of sustainable buildings to understand which vernacular materials and techniques are good for green building

delivery. For policymakers, because these vernacular materials and techniques have excellent sustainability benefits associated with them, they could establish and implement policies aimed at promoting and incorporating such materials and techniques in green building delivery.

There are some limitations to this study. First, since laterite and clay/clay bricks are all earth-based materials, they should have been considered holistically in the paper. It is, therefore, an acknowledged fact that the findings concerning these materials could have been different from the current findings if this had been done. Based on this any future study that looks at these materials could consider them holistically and not as individual materials. Secondly, though there exist quite a good number of built environment professionals within the study locations, getting those professionals who had in-depth knowledge concerning the issue under investigation was difficult. Since the green building is somewhat new in the Ghanaian system, most professionals tend to shy away when approached for their inputs concerning the concept. This problem greatly influenced the responses to the study. Though the study provides some good outcomes, generalizing the results is problematic because of the small sample size. Future studies could consider a sizeable number of built environment professionals with an in-depth understanding of the concept of green buildings to enable a better generalization to be made.

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Declaration of Competing Interest

None.

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